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Dpt. for Media Engineering and Technology
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# CSEN 1001: Computer and network security

## Spring 2013

Final exam

**Model Solutions**

**Instructions. Please read carefully before proceeding.**

(a) The duration of this exam is **180 minutes**.

(b) Non-programmable calculators are allowed.

(c) No books or other aids are permitted for this test.

(d) This exam booklet contains a total of **10 pages**, including this one.

**Please checkmark your major and exam type!**

☐ CS (computer science)

☐ DMET (digital media engineering and technology)

☐ Regular final

☐ Midterm/final (excused for midterm)

☐ Makeup / second makeup

**Exercise 1** Key Management (6 Marks)

Alice and Bob have each generated a public and private key pair. However, they do not know each others' keys yet. Now they are trying to exchange a message $M$ over a network.

(a) What is the procedure to exchange the message confidentially, if only passive attacks need to be considered? (3 Marks)

**Solution:**

It is sufficient to exchange each others' public key by e-mail before the actual conversation. Afterwards, they can encrypt the message with the partner's public key.

(b) What can be done to mitigate the risk if active attacks are possible? (3 Marks)

**Solution:**

To ensure the authenticity of the public keys, either a personal interchange or a trusted third party is necessary. Exchanging the keys over a network without a public-key/certificate authority will open the communication to a man-in-the-middle attack.

**Exercise 2** MCQ (16 Marks)
**Mixed trivia and understanding**

(a) Choose the correct answer and **state the reason**.

(i.) When exchanging a key, Diffie-Hellman is used to counter ... attacks (3 Marks)

☑ Passive
☐ Active

Reason:

**Solution:**
Diffie-Hellaman can be only used to counter **Passive** attacks. A Man-in-the-middle can intercept the $A$ being sent from Alice to Bob, generate his own $g^e$ then send it to Bob. And again intercept $B$ being sent from Bob to Alice, and send $g^e$ to Alice. Now only Eve can understand the messages sent to/from Alice and Bob. Thus Active attacks *are* possible.

(ii.) In Public/Private key cryptography, even the sender will no longer be able to read the message after encrypting it with the receiver's public key. (3 Marks)

☑ True
☐ False

Reason:

**Solution:**
**True**. Because only receiver has the private key that can decrypt the message.

(iii.) In the Advanced Encryption Standard (AES) cipher, "shift rows" is a step that contributes to... (3 Marks)

☐ Confusion
☑ Diffusion

Reason:

**Solution:**
**Diffusion**. Because shift rows involves permutations.

(iv.) RSA is an example of ... ciphers. (3 Marks)

☐ Symmetric
☑ Asymmetric

Reason:

**Solution:**
**True**. Because only receiver has the private key that can decrypt the message.

(b) Check **all** that apply

(i.) The Data Encryption Standard (DES) is based on (2 Marks)

☑ Feistel Cipher
☐ Stream Cipher
☐ Rijndael Cipher
☐ Vigenère Cipher
☐ Caesar Cipher

(ii.) The Caesar Cipher is a(n) (2 Marks)

☐ SP-Network
☐ Block Cipher
☑ Stream Cipher
☑ Substitution Cipher
☐ Permutation Cipher

**Exercise 3** Mathematical cipher attacks (6 Marks)
**Diffie-Hellman key exchange**

Alice and Bob use the Diffie-Hellman algorithm to exchange a secret key. Eve intercepts the following values:

$$p = 283$$
$$g = 12$$
$$A = 77$$
$$B = 196$$

(a) What are the steps for Eve to compute s? (3 Marks)

**Solution:**

Eve has to calculate the discrete logarithm of A base g modulo p (*i. e.*, a) or the discrete logarithm of B base g modulo p (*i. e.*, b).

Assuming Eve found a, then $s = B^a \mod p$. Otherwise $s = A^b \mod p$.

(b) You are Eve. Actually compute s. (3 Marks)

**Solution:**

Try the possible values for $a = \{1, 2, 3, \ldots, 282\}$.

$$12^1 \mod 283 = 12 \quad \ldots \text{no.}$$
$$12^2 \mod 283 = 144 \quad \ldots \text{no.}$$
$$12^3 \mod 283 = 30 \quad \ldots \text{no.}$$
$$12^4 \mod 283 = 77 \quad \text{success!}$$

So $a = 4$, therefore $s = B^a \mod p = 196^4 \mod 283 = 90$.

**Exercise 4** Stream and Block ciphers (15 Marks)
**Vigenère, One-time-pad, and Running Key cipher**

In this exercise we develop a relatively secure cipher from the idea of the Vigenère cipher but still find a vulnerability. The scenario is that Alice wants to communicate a message (a lengthy text in English) to Bob without Eve being able to read it.

(a) Imagine that instead of a password of finite length, Alice and Bob chose a virtually infinite password (*i. e.*, the password is at least as long as the message) for a Vigenère cipher. For simplicity they secretly agree on using the text of the five books of the "Hitchhiker's Guide to the Galaxy" trilogy by Douglas Adams as the password (keystream).

Which of the following attacks **works** on a standard Vigenère cipher but **does not work/is not feasible** on this variation? Check all that apply and give a short explanation: (5 Marks)

☐ Frequency analysis

**Solution:**
As message and keystream are English texts, letter frequencies are preserved. Thus, frequency analysis works on both variations.

☐ Previously computed table of discrete logarithms

**Solution:**
Right. That one works on neither of the variations.

☑ Kasiski analysis

**Solution:**
A Kasiski analysis finds the length of the keyword. This no longer applies.

☐ Pattern word attack

**Solution:**
Any pattern word that leads to intelligible results is likely in the correct position. This works on both variations.

☑ Brute force

**Solution:**
For brute force the entropy of an infinite length password is too high.

**Note.** This type of cipher is called a **Running Key cipher**.

(b) Since the Vigenère lookup in the tabula recta is tedious to implement on a computer, Alice and Bob decide to use the ASCII code representation of message $M$ and keystream $K$ and instead of the table lookup perform a bitwise XOR ("$\oplus$") to obtain the ciphertext $C$, so

$$C = E_K(M) = M \oplus K, \text{ and}$$
$$M = E_K(C) = C \oplus K.$$

Is the cipher now more secure (*yes* or *no*)? Explain! (2 Marks)

☐ Yes.

☑ No.

**Solution:**
No. There is still a unique and simple relation between the two inputs and the result. It is the same as working with a permutation of the tabula recta.

(c) Regardless of what you found out above, let us assume that encrypting English text with English text is **insecure**. In other words, if $C = M \oplus K$ and $M$ and $K$ are both English texts, then there is an attack on $C$ that can reveal $M$ and $K$.

If Alice and Bob decide to use a high quality pseudo random number generator for the keystream instead of the Douglas Adams novels, will the cipher be more secure (*yes* or *no*)? Explain! (2 Marks)

☑ Yes.

☐ No.

**Solution:**

Yes. If the keystream is perfectly random the Running Key cipher is the same as a One-time-pad method. Thus, the cipher is secure.

(d) Again, assume that encrypting English text with English text is **insecure**, and for this part assume that encrypting English text with a good random stream is **secure**.

Alice sends to Bob two messages $M_1$ and $M_2$ of the same length, encrypted using the same high quality pseudo random keystream $K_0$ with the same seed, so with exactly the **same key twice**:

$$C_1 = M_1 \oplus K_0, \text{ and}$$
$$C_2 = M_2 \oplus K_0.$$

Unfortunately, Eve intercepts both messages. Show how (under the above assumptions) Eve can extract both messages $M_1$ and $M_2$ from only $C_1$ and $C_2$. (6 Marks)

**Hint.** Note that $\oplus$ is commutative and that for all $X$ we have that $X \oplus X = 0$ (self inverse). What else?

**Solution:**

First, Eve computes $C_1 \oplus C_2$, since

$$\begin{aligned} C_1 \oplus C_2 &= (M_1 \oplus K_0) \oplus (M_2 \oplus K_0) \\ &= M_1 \oplus M_2 \oplus K_0 \oplus K_0 \\ &= M_1 \oplus M_2 \end{aligned}$$

However, $C_1$ and $C_2$ are both English text. Citing above assumption that encrypting English text with English text is **insecure**, Eve can now decrypt the two texts and obtain $M_1$ and $M_2$.

**Exercise 5** Avalanche effect (5 Marks)

(a) Given an encryption function $f(x)$, what kinds of trials can you do in order to check whether or not it achieves diffusion? (2 Marks)

**Solution:**

We can try two strings that are different in only one element, for example: f(ABCD) and f(ACCD). If at least 50% of the resulting cipher text of one of the inputs is different from that of the other, then we can conclude that it achieves diffusion, and vice versa.

(b) Which of the main components of an SP-Network contributes to confusion, and which contributes to diffusion? and why? (3 Marks)

**Solution:**

The two main components are:

- S-box: contributes to confusion, as it substitutes elements for others, this way making the relationship between the plain and cipher text weaker.
- P-box: contributes to diffusion, as the permutation steps are essential in order to reach a totally different cipher text if only one element of the plain text is changed.

**Exercise 6** Security management (12 Marks)
**Cloud service**

You are responsible for the security of a cloud storage and computing service. Naturally, you need to protect your customers' data by fully encrypting their reserved blocks on your server. You distinguish:

**IT team.** This team has access to the server and all system files for maintenance.

**Executive team.** This team has access to customers' addresses and billing data.

**The customers.** Each customer has access to his reserved block on the file system.

(a) When a customer enters/edits their billing data, it has to be protected from unauthorized access. Choose one of the following encryption schemata (explain your choice): (1 Mark)

☐ triple DES
☑ RSA
☐ AES

**Solution:**

RSA is the only choice that offers asymmetric encryption. However, the scenario demands that encrypting is available automatically, while decryption is restricted to the executive team.

(b) Given your choice above, write for each group which key should be available to them (write the key type or "*none*"): (1 Mark)

**Solution:**

- IT team: RSA public key for customer data
- Executive team: RSA private key for customer data
- Customer: *none*

(c) The IT team has access to the system files, including sensitive files such as `/etc/passwd`. Describe how you prevent them from using an executive team member's credentials. (2 Marks)

**Solution:**

Use *salted hashing* to mask the passwords before storing. The salt-hashed passwords are generally stored in `/etc/shadows`.

(d) Sales expert Alice (executive team) does not have PGP/RSA installed on her private e-mail client, however she does have a public/private key pair which she uses when communicating over her corporate mail client. She wants to send a sensitive message to sales expert Bob as she often does, however she currently cannot use the corporate client. She considers two options:

(1) She sends this one e-mail unencrypted.
(2) She uses an online encryption/decryption service she found at `www.isilver.com`, where she can submit the message and Bob's public key and receives a ciphertext which she sends to Bob. Bob can likewise decrypt the ciphertext by uploading it together with his private key to the same site.

Which option poses the **greater** security risk? Please explain! (2 Marks)

**Solution:**

Option (2) poses by far the greater risk. With option (1), one e-mail can possibly be intercepted and read. Option (2) however potentially exposes Bob's private/public key pair, opening all his conversations to an eavesdropper.

(e) Which algorithm would you use to secure the customers' data inside their blocks? Explain your answer. (2 Marks)

☑ AES
☐ DES
☐ RSA

**Solution:**

Simple DES is no longer considered safe. RSA is computationally expensive and not suitable for encrypting large blocks (even in e-mail communication, RSA is only used for encrypting a session key, the actual message is encrypted with triple DES.

(f) Based on your choice above, who should hold which key for the customer data? Write the key type or "*none*": (1 Mark)

**Solution:**

- IT team: *none*
- Executive team: *none*
- Customer: The AES en-/decryption key.

(g) Propose a mitigation against flooding of your service by bots masking as new customers. (1 Mark)

**Solution:**

Employ a CAPTCHA.

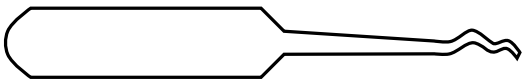
(h) Which precautions are necessary at a minimum to mitigate customer-interface-side attacks on your site? (2 Marks)

**Solution:**

Sanitize/escape all inputs to prevent SQL injections or cross site scripting.

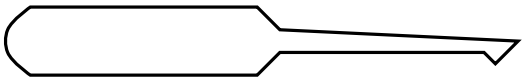
**Bonus Exercise 7** Physical security (3 Marks)
**Simple devices**

Please name instruments given below as schematics

(a)  (1 Mark)

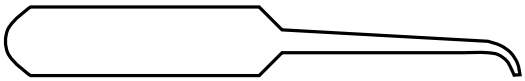
**Solution:**

*Snake*. Use this for quick opening of cheap tumbler locks.

(b)  (1 Mark)

**Solution:**

*Half diamond*. Use this for setting pins in normal grade tumbler locks.

(c)  (1 Mark)

**Solution:**

*Rake*. Use this for quick opening attempts in normal grade tumbler locks.